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ABSTRACT

The needs of research universities are discussed in a statement before Congress, with attention to graduate education, young researchers, research instrumentation, and research facilities. The increasing overhead costs associated with doing research are also addressed, along with the appropriate federal role in fostering university/industry partnerships. There is a serious shortage of graduate students in certain fields, and federal support for graduate education has been substantially reduced. Difficulties face young researchers in their careers. Out-of-date research equipment is also a concern, as the most serious problem facing research universities is deteriorating research laboratories. The six major research agencies of the government should cooperatively address these priority areas facing research universities. Some of the issues are illustrated by the experience at Cornell University. (SW)

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STATEMENT

before the

Committee on Science and Technology

U.S. House of Representatives

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by

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on behalf of the

Association of American Universities
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American Council on Education
Association of Graduate Schools
Council of Graduate Schools

HE017 392

May 8, 1984

Mr. Chairman, Members of the Committee on Science and Technology:

My name is Frank Rhodes, and I am President of Cornell University. I have the pleasure this morning of representing the 50 major research universities that comprise the membership of the Association of American Universities. I am also representing the American Council on Education, the National Association of State Universities and Land-Grant Colleges, the Association of Graduate Schools and the Council of Graduate Schools in the United States.

As this Committee knows well, these associations together represent essentially all of the nation's universities and colleges that carry out the research and related education programs supported by the National Science Foundation, the National Institutes of Health and other mission agencies of the Federal Government.

Introduction

The research and development base which this nation has created over many decades remains the strongest and most productive in the world. In spite of our strength, however, there is evidence that the gap between us and our foreign competitors is narrowing, partly because of increased investments in science and technology, and partly because of the erosion in our own research base.

In 1969, our national R&D expenditures were more than twice the combined R&D expenditures of France, Japan, the United Kingdom and West Germany. Just ten years later, in 1979, the combined R&D expenditures of those four countries equalled ours.

Our R&D expenditure as a percentage of our Gross National Product is less than that of most other nations. We have, for example, trailed West Germany for 10 years and the USSR for the last 15 years in this expenditure. If one looks at civilian R&D expenditures as a ratio of GNP, the comparisons are equally revealing: U.S. 1.69, Japan 2.30, West Germany, 2.53.

In spite of recent increases in research and development expenditure, the basic research component of those increases has been modest, and we now face serious problems in the nation's basic research effort. Let me then address the needs of our research universities in four areas:

- graduate education
- young researchers
- research instrumentation
- research facilities

In response to your request, I shall also be glad to say something about the increasing overhead costs associated with doing research, and about the appropriate Federal role in fostering university/industry partnerships. I shall try to cover highlights briefly in my testimony, Mr. Chairman, and hope that you will accept the full written statement for the record.

Graduate Education

Our world seems to grow more complex and more insecure at every turn. Our graduate schools provide the continuing supply of talented individuals with the knowledge, technical skills and perception on which our national security, our economic strength and our cultural vitality depend.

Assuring a continuing infusion into our society of such talent must be a national -- and federal -- priority. Let me give a few examples of the recent fruits of basic research in the medical field which illustrate the direct benefits of research. Medical research has:

- increased the survival rate of childhood cancer victims from 5 percent to 57 percent between 1962 and 1982;

- developed recombinant DNA technology -- with all its potential benefits

- reduced the death rate from coronary heart disease by 30% since 1970 (saving 148,000 lives and an estimated $7.7 billion in 1982 alone); and

- contributed over $40 billion to the GNP each year from non-health related products -- more than the total federal investment in basic research over nearly 50 years.

Federally funded fellowships have been a clear success and an important, even determining, factor in the careers of numerous researchers who have contributed to these and other successes.

But we now face a serious shortage of graduate students in certain fields. For 15 years, federal support for graduate education has been substantially reduced. The number of federally funded graduate fellowships in the physical sciences and engineering has declined from 51,000 in 1968 to about 1500 today. In the face of sharply increasing international competition, critical national needs served by graduate education are going unmet.

The present Administration proposes small, highly targeted increases in university research and development, most notably in the areas perceived to be of closest significance to the national defense. The budgets of three agencies -- NSF, DOD and NIH -- illustrate the limitations of this strategy in providing a solution to our problems.

The Department of Defense proposes to increase its investment in university research programs at a level slightly above inflation, and to award the third class of 40 graduate fellowships designed to attract undergraduates into graduate programs in fields linked to our national security needs. DOD also has undertaken a five-year, $150 million program to upgrade research instrumentation in laboratories that carry out research programs in areas related to our defense needs.

However, the DOD research initiatives, commendable as they are, are at risk at the moment in the House version of the DOD authorization bill for FY-1985.

The FY-1985 budget request for the National Science Foundation is much more encouraging. Augmented in the House Authorization bill by the increases proposed by this Committee, it provides for significant real increases in the Foundation's physical sciences and engineering programs, with somewhat smaller increases proposed for other fields.

Moreover, after almost a decade of neglect, additional steps to strengthen the NSF graduate fellowship programs are proposed. Targeted attention also is being proposed to assist young researchers, who with some encouragement at a crucial point in their careers, may now pursue careers in academic science.

The NSF budget is the centerpiece of the Administration's FY-1985 budget for university research, and I want to express thanks to Dr. Keyworth, Dr. Hess and their associates for these timely initiatives.

I also want to take this opportunity to express to you, Mr. Chairman, and to the members of your Committee, the appreciation of the research university community for your leadership in strengthening the NSF budget and in skillfully negotiating the passage of the authorization bill. These are welcome first steps toward a more comprehensive, government-wide investment strategy to strengthen basic science and graduate education.

In sharp contrast to the DOD R&D budget and the significant proposals in NSF is the sharply restrained request for NIH research activities. The budget request for NIH and ADAMHA once again is below levels needed to sustain even the present research activity. We hope that the members of this Committee and the Congress will again support efforts to protect and sustain university biomedical research and advanced training programs.

There remains an urgent need to attract some of our most able young research workers in science and technology into fields of public priority. The new competitive graduate fellowship program of the Office of Naval Research offers an excellent model for NSF and the other mission agencies. The program offers talented students competitive three-year fellowships with stipends of $13,000, plus full tuition and a $2,000 research award to the host department. The Navy imposes no employment requirements. The motivation of the ONR program is to find and attract a few of our best young minds into advanced education in fields of science and engineering of interest to the Navy.

A stronger, more balanced approach would provide for small graduate fellowship programs in each of the major mission agencies. These would provide for a) merit-based, portable, three-year graduate awards to individuals, and b) an equal number of awards made to students through institutions with high quality graduate departments that carry out basic research programs of interest to each agency. Such a shared effort could provide a total of 1500 to 2000 additional awards annually, for relatively small investments by each agency. The mechanisms are well known, proven and mutually reinforcing. Particular attention needs to be given to the serious shortage of minority students in graduate research programs.

Young Faculty

Closely linked to the needs of graduate students are the increasingly serious challenges that face young faculty in their early careers in research. The attractiveness of an academic career is being diminished by an environment which often provides only outdated equipment and inadequate laboratory space.

We commend the new NSF Presidential Young Investigator Awards program, which is entering its second year with the FY-1985 budget request. The first 200 awards were announced recently. It is encouraging to note that more than 20 of the first class of awards went to women. It is important that this new program proceed uninterrupted during the five-year cycle of the awards.

But the support of young faculty ought not to be the sole responsibility of the National Science Foundation. We urge the Committee to exercise its leadership to encourage the appropriate committees of the House to add small initiatives for this purpose to the research programs of DOE, NASA, USDA, DOD and NIH.

Research Instrumentation

The instrumentation and equipment now being used in many of our research and training laboratories is seriously out of date. This is well documented by survey results, just published by the NSF, of university research instrumentation systems in three selected fields -- computer and physical sciences and engineering. The report produced the following findings:

- one-fourth of the 1982 research equipment inventory in these fields, which had an aggregate purchase price of $904 million, is obsolete and no longer in research use.

- only 16% of all academic research equipment inventoried is state-of-the-art.

- more than 90% of departmental chairpersons surveyed reported that the lack of equipment inhibited the conduct of critical research.

- 31% of all instrument systems in use in 1982 was more than 10 years old.

- contrary to the expectations of some, university researchers do share equipment at significant levels. Each instrument system in service in 1982 was used by a median of seven researchers. The median number using each piece of computer sciences equipment was 25 researchers.

- 46% of the chairpersons rated the quality of support services (e.g., machine shop, electronics shop, etc.) as "insufficient" (40%) or "non-existent" (6%).

The survey also revealed useful information about current sources of support.

- NSF is the leading federal sponsor of research equipment purchases in the physical and computer sciences, providing about 52% of federal support in these two fields.

- DOD is the primary federal funding agency in engineering, accounting for 45% of the federally financed engineering research equipment.

- nonfederal sources play an important role. In 1982 78% of computer sciences instrument systems, 64% of engineering systems and 52% of physical sciences instrument systems were not federally funded in their entirety. Universities' own funds accounted for at least 70% of the non-federal funds used for equipment in each of these three fields.

- industry funds accounted for 10% of non-federal research equipment purchases.

These new NSF data more than justify sustained investment by NSF and the major mission agencies in university research equipment.

This continued federal investment, while essential, is an insufficient response to the problem. We must search for alternative solutions to make certain that scarce resources are fully utilized. Therefore the AAU, the National Association of State Universities and Land-Grant Colleges and the Council on Governmental Relations have undertaken a study project designed to explore alternative solutions to the equipment problem. The project seeks to identify and evaluate new approaches to acquiring, managing and using equipment, and to inform the university community and others of the results of these evaluations. The project is being supported by six agencies: NSF, DOE, DOD, NIH, NASA and USDA.

A summary of the topics being addressed by the project was presented to this Committee on February 28 by Dr. Robert Rosenzweig, President of the Association of American Universities. I need not discuss it further here, other than to say we are very pleased that these issues have the attention of these agencies and we are looking forward to an interesting and productive result.

Research Facilities

A preliminary NSF survey of 25 universities, just released, conservatively estimates that research universities and colleges require $1.3 billion per year to meet accumulated research facilities needs. In FY-1984 the total Federal investment in R&D plant in universities and colleges is projected to be $40 million, and essentially all of these funds are targeted on special purpose user or national facilities.

I know that this Committee, and other Committees of the House, have begun an effort to understand and address the problems associated with deteriorating research laboratories. A year ago this Committee asked NSF to consider the question, and the House Committee on Armed Services directed the DOD to carry out a comprehensive assessment of the research facilities needs of universities engaged in DOD-sponsored research. We understand that an interagency group is now at work planning that effort. We hope that the Committee will follow that NSF-led effort with interest and encouragement.

There is now no general reinvestment effort by NSF or by any mission agency specifically designed to help with the modernization of the university research laboratories in which agency funded programs are carried out. Just as several agencies have begun to address the research equipment problem, we urge the Committee to ask them also to achieve a shared assessment of the facilities problem by field and to fashion a comprehensive government-wide approach to address it. This is, I must emphasize, the most serious long-range problem facing our research universities.

Throughout these remarks, I have suggested that all of the six major research agencies of government join together to address the four priority areas: graduate education, young faculty, research instrumentation and facilities modernization. Only a shared long-term reinvestment plan and funding strategy will provide the breadth and concentration of resources, consistent with the missions of the agencies, necessary to address the needs.

One such approach has been introduced in the Senate. S. 1537, the "Research Capacity Restoration Act of 1983," has been cosponsored by 20 Senators. I understand that discussions of such a proposal are proceeding in the House. We hope that this Committee will support such a reinvestment plan. I do understand the difficulty of addressing issues of such magnitude in the current budgetary climate, but a solution must be found if our university research capacity is to be preserved.

Experience at Cornell University

I should like to illustrate some of the issues I have addressed with the experience of my own institution. Cornell is among the nation's leading research universities. Sponsored research expenditures in the last fiscal year exceeded $150 million with NSF and NIH being the major sponsors. Our research programs are open and accessible to all who would draw from them. They are fully integrated into our educational programs and we

are a major producer of young people educated to serve our national needs. It is vital to the national well being that we provide these young people not only with the opportunity to learn from a group of the nation's leading research workers, but also with the instrumentation and facilities that maximize their value to our society.

I will give a few examples of our needs in these areas.

Universities deal with knowledge. We make it, transmit it, store it and use it. Effective storage and use of knowledge requires effective libraries. The exponential growth of new knowledge makes it ever more difficult to use knowledge well -- or to store it, for that matter. Computers hold the promise of helping to solve the dilemma but the cost is high. Cornell's library of more than 4 million books can be made accessible to users, as can the resources of other research libraries, but the cost will be more than $6 million in "front-end" costs and an added $1 million in operating costs for at least the first five or six years. There is little likelihood that this long-term cost will decrease.

Cornell operates, with NSF funding, a Materials Science Center. This collaboration between physicists, chemists, and engineers is the largest of fourteen such programs funded by the Foundation. It has operated for 25 years and has contributed significantly to the nation's economy through research and highly trained personnel in the properties and uses of materials so essential in many applications in manufacturing, construction, and fabrication. This fundamental but interdisciplinary area of

study intersects every aspect of our daily lives. From the buildings we live in, the cars we drive, the surfaces we drive on, the clothes we wear, to the medical devices we implant -- the list is inexhaustible.

For the past decade, the Cornell Materials Science Center has made capital equipment one of its highest priorities. (The other is start-up support for new, young, faculty.) The Center allocates a minimum of 15% of its budget to capital equipment each year. In some years, the allocation exceeds 20%. These funds are supplemented from time to time by major individual equipment grants. It is anticipated that this policy will be continued into the foreseeable future.

There has been an unprecedented and explosive development in new, sophisticated research equipment in the past 20 or so years, fueled by major advances in electronics and computers. Industry and government have had greater resources than the universities and this has led to a substantial equipment gap. It is nevertheless the Center's estimate that it is not closing the gap in comparison with the equipment resources available in major industrial and government laboratories.

The University, within the last two weeks, has made a very substantial commitment of funds to help the MSC sustain its equipment base and to make it more useful to researchers from Cornell, other universities, and industry. We have proposed to NSF that we will provide $600,000 to assist in the purchase of three major items of equipment that will cost a total of $2 million. NSF is asked to provide the remainder. The

individual items, all essential to the study of surface phenomena in industrially important materials, cost $950,000, $700,000, and $350,000 (two electron microscopes, each very different in function, and a device for depositing and analyzing thin films).

It may sound as though this is a "good deal" for the University and in fact it is. The University's problem is how and where to find such major sums of money. The cost of the equipment needed is increasing much more rapidly than inflation. It is not a matter of simply replacing worn out instruments. The new instruments extend our ability to measure and evaluate. They go well beyond instruments they replace in performance as well as in cost.

In the general area of materials science research, despite the commitment I have just described, we can identify a need for more than $4 million of new equipment at Cornell. Without it, our value as a research and teaching resource will inevitably be compromised. We have no source to which to turn for these funds.

A closely related area is long-term research in support of computer chip development. Cornell operates a very successful National Submicron Facility. It is the only center of its kind supported by the NSF. Cornell provided funds for the construction of the facility. NSF provided funds for equipment, and both provide operating funds -- as does the semiconductor industry through a grant from the Semiconductor Research Corporation.

In this vital area, we have identified a need for more than $5 million for new equipment during the next three years.

A third example of new equipment needs is less specific but it is, nonetheless, real and a very important deficiency. As young people replace retiring faculty, the areas and emphasis of programs change. New faculty members need laboratories with new capabilities and new, often different, kinds of equipment. Typically, we must find between $100,000 and $300,000 to equip a laboratory for a new faculty member. We don't always succeed. When you realize that we may appoint 20 or more young scientists a year you can understand why. To the extent that we cannot provide the best possible start for these young faculty members, we limit our technological growth and the value of these faculty members to our society.

The situation with respect to new facilities is even more acute. In areas where we have great scientific competence, we have identified more than $100 million in facilities needs. These areas include biotechnology, plant and molecular biology, microbiology, animal reproductive biology, veterinary medicine, astronomical and atmospheric sciences, electrical engineering, materials sciences, computer simulation and theoretical computations, social and economic sciences, computer sciences, and manufacturing technology. All have been identified as areas of national priority. All are areas in which we have the human potential to make a much greater contribution.

In concluding this portion of my testimony, I should like to quote from Richard DeLauer, Under Secretary of Defense for Research and Engineering, who recently wrote to the President: "Since the mid-70's . . . we have allowed our technological lead to erode and our support for education and research to decline. Our research and teaching institutions already are having serious difficulties producing the quality scientists and engineers needed to regain the technological lead so essential to our future security and economic well being."

Indirect Costs

The past two years have seen increased attention paid to university indirect cost rates for federally sponsored research. In FY '83 and '84, the Department of Health and Human Services proposed cutting reimbursement of indirect cost by 10%. Universities objected to this proposal as arbitrary and destructive of the institutional capacity to conduct federally-sponsored research. This proposal is not part of the Administration's FY '85 budget; the President's Science Advisor has proposed a study of the issue in the context of the universities' continued capacity to undertake federally funded research.

As you know, cost-based reimbursement replaced a fixed rate in 1965. At that time, the federal government decided that institutions should be reimbursed for the actual cost of the research (after factoring in mandatory cost sharing) instead of a flat rate.

In the period following the removal of this cap, indirect costs have risen to reflect the actual costs of the research. These include inflation (which disproportionately affects indirect costs), increasing federal regulation, and the federally instituted requirements for more detailed cost accounting. To sum up the major reasons for the increase in indirect costs as a percentage of total costs:

1. Indirect costs were artificially capped in the years before 1966.

2. Inflation has resulted in a greater rise in non-personnel costs than in salary costs.

3. The cost of compliance with government mandated health, safety, social and administrative standards has increased.

4. The nature of research has changed: it is more complex and requires greater institutional support; research teams and projects are larger; more equipment and other resources are shared and the costs are charged to indirect cost categories instead of direct cost categories.

5. Legitimate costs of research, once covered by university resources, must now be recovered through indirect cost reimbursement.

6. In a period of increasing financial stringency, universities have practiced better management and have improved identification of costs.

The most recent revision of OMB Circular A-21 (which sets forth the basis upon which indirect costs are calculated) included allowance for interest paid to external sources for construction and renovation of facilities. While this change was welcome, it is not likely that it will contribute significantly to the renovation or construction of university research facilities in the foreseeable future. There are two reasons for this:

1. The advantages in indirect cost recovery accrue only after the institution has obtained funds for facilities from an "external source;" such funds are not available on a significant scale.

2. Concern over increases in indirect cost rates is such that universities are reticent to take any actions that will increase them.

It should not be overlooked that indirect cost rates are always approved retrospectively, in discussions which involve continuous and detailed federal audit of all costs already incurred.

The Role of Government in Fostering University-Industry Relationships

Industrial support of university research is one of the most significant developments of recent years, but the significance

can be easily overstated. The magnitude of industrial support is now about 3% of total university research expenditures; few experts see it ever rising to more than 8-10%. Further, industrial support is not a new phenomenon. It has existed for decades in a great many of our leading institutions.

Still, the magnitude of recent developments constitutes significant change. In every year since 1970, industry funding of university-based research, in constant dollars, has increased. Total funding doubled between 1970 and 1983; it increased by 11% in 1980-81 alone. According to Science Indicators 1982, half of the support is in engineering.

A variety of funding mechanisms, institutional arrangements and cooperative agreements are in place and more are being developed. Often the award of an equipment grant from the NSF, DOD or another agency is proving to be a catalyst in the formation of these new arrangements. So an important side benefit of federal investment in research equipment is the stimulation of new research relationships between industry and university researchers who are appropriately equipped to address research questions of interest to industry.

One of the most significant incentives developed by the Federal government to stimulate industry support for university research activites is the provision of the Economic Recovery Tax Act of 1981 which encourages the donation of research equipment to universities. This appears to be having a very significant

impact, in certain corporations. It ought to be strengthened to provide for the donation of instructional equipment, for equipment previously used by the donor for less than three years, and to remove present ambiguities over the donation of computer software.

This tax incentive clearly is valuable where large corporations are concerned. In the case of small, innovative companies, however, different kinds of stimuli are needed to assist in the development of sophisticated new instrumentation. University researchers have special requirements for this kind of instrumentation, and can play an important interactive role in assisting a small company to meet the difficult challenges involved. We need to find new ways to assist in procuring such instrumentation and to assist the industry-university interaction to take place.

The Economic Recovery Tax Act also provides an incentive for the support of university-based research. The effectiveness of this particular provision is somewhat more difficult to assess, but in time this too may prove helpful.

Research is the foundation of our national progress. Our economic strength, our industrial productivity, our cultural vitality, our people's health, our international leadership, our national security - all these and more depend upon it. With a strong research base - governmental, industrial, academic - we shall prosper. Without it - we shall decline. To neglect the research enterprise is to mortgage our nation's future. To underfund it is to impoverish our people and to abdicate our international leadership to others.

'The nation that undervalues trained intelligence is doomed' declared Alfred North Whitehead, many years ago. That judgement stands. Time has reinforced its truth. Federal support of trained intelligence and its application in creative research and vigorous development is not one claim amongst countless competing claims, however admirable or worthy their goals may be. It is the prerequisite for all other goals, the best hope for their achievement, the foundation of their eventual implementation, the basis of our national well-being.

Mr. Chairman, these hearings have raised questions of major importance. Our present responses to them will influence our national life well into the next century. We wish to commend and thank you and the Committee for raising these fundamental issues.

I will be pleased to answer any questions you may have.

U. S. Research and Development: The Changing Scene

National Expenditures for Research and Development

Total national R&D expenditures have grown steadily in recent years, although the basic research component of that growth has been modest. According to a recent report by the Congressional Budget Office, Federal Support for R&D and Innovation, R&D funding has increased 41 percent since 1980 (an increase of 10 percent in real terms). In FY-1984, according to figures prepared by the American Association for the Advancement of Science (AAAS), total national funds for R&D will be $97.9 billion, an increase in current dollars of more than 11 percent (6.2 percent in constant dollars) over 1983.

Inflation, however, has taken a severe toll on the nation's total investment efforts. A sixfold increase achieved during the period 1960 to 1983, adjusted for inflation, is only doubling. (Universities and colleges more than tripled their own investment in R&D over this period of nearly a quarter century.)

The federal role in R&D is changing, both in the magnitude of the federal investment and the character of the work being supported. Defense-related R&D, including Department of Energy (DOE) defense spending, has grown from 48 percent of the total R&D budget in 1980 to 70 percent in 1984 -- a real increase of 53

percent. Most defense R&D funding is for development, not fundamental research. According to the Congressional Budget Office report cited earlier, DOD spends by far the smallest proportion on basic and applied research of all the major agencies that fund significant amounts of R&D. If defense-related development funding is omitted, the real funding for R&D in FY-1984 is only 78 percent of the 1980 level.

While the Administration has increased defense-related R&D, it has cut civilian applied R&D and at the same time provided a compensatory government-wide increase for basic research of 10 percent over four years. This de-emphasizes applied research, often seen as the bridge to technological innovation and industrial development.

The R&D role of industry is also changing. In 1980, for the first time in 20 years, industry invested more than the federal government in R&D. In 1984 industry accounted for an estimated $50 billion in R&D expenditures, slightly more than half the national total. Thus industry has become the largest source of R&D support in the U.S. Most of industry's investment, as in the case of federal defense R&D, is in development, not fundamental research.

Universities also fund research from their own or donated sources. These funds typically are spent to augment particular research programs or to provide seed funds for young investigators. In 1984 universities and colleges spent an estimated $1.7 billion of their funds for research, a sum equal to just 3 percent of the total industrial effort. Science

Indicators, however, projects a decline in R&D support provided by the academic sector. The same report projects expansion in industry R&D investment (which grew between 1980 and 1983 at an annual rate of 5.4 percent in constant dollars), and in federal investment (which grew at a rate of 3.1 percent).

As a performer of R&D, industry accounted for 75 percent, or $73 billion, of the total national R&D effort in 1984. Government intramural laboratories accounted for $11 billion. It is predicted that universities and colleges this year will perform a total of $8.4 billion of the total $97.9 billion national R&D effort.

To illustrate the effect of inflation, academic R&D grew at an annual average rate of 12 percent during the 1960's. That slowed to 2.8 percent in the 1970's. In constant dollars, expenditures for academic R&D are estimated by Science Indicators - 1982 to have declined slightly between 1980 and 1983.

National Expenditures for Basic Research

Most academic R&D historically has been basic research. Science Indicators - 1982 estimates that 25 percent of all research and about 50 percent of the nation's basic research is carried out in university laboratories. The primary national

sources of support for university basic research are NSF, NIH and the other mission agencies of the government. Together they account for 70 percent of the total national support for basic research, and they also provide about 70 percent of the total investment in academic basic research.

Measured in constant dollars for the period 1960 to 1983, the total national investment in basic research grew almost threefold from $1.7 billion to $4.8 billion. The federal share of that investment grew from $1 billion to $3.2 billion. Industry expenditures increased by a factor of 1.8, from $497 million to $914 million. (Industry's real-dollar expenditures for applied research almost tripled and investment in development quadrupled.) Universities and colleges increased their own constant dollar investments in basic research fourfold, from $103 million to $440 million.

Trends in Academic Science and Engineering

One hundred years ago, fewer than 2 percent of our citizens between the ages of 18 and 21 enrolled in higher education. Now 30 percent of the individuals of college age are enrolled in our 3000 or so universities and colleges. One-third of our four-year institutions have been established since 1960; 1447 of our four-year colleges offer science and engineering degrees.

The number of institutions offering advanced science and engineering degrees has doubled since 1960. The number of advanced degrees in science and engineering awarded annually has tripled since 1960. At the same time, our universities have retained a great commitment to and investment in undergraduate education. In 1980 doctoral institutions awarded 54 percent of all baccalaureate degrees conferred in the country.

The total enrollment of science and engineering students increased dramatically during the 1960's, and now it is roughly stabilized at slightly below historically high levels. Important shifts, however, have occurred within and among specific fields. These changes will affect our capacity to meet the nation's future scientific and technological needs.

Changing enrollment patterns in key fields, such as computer sciences and engineering, are creating serious problems for universities in recruiting young faculty. Between 1970 and 1981 the number of bachelor degrees in the computer sciences increased tenfold (from 1500 to 15,000). Undergraduate engineering enrollments are at a high point, with students drawn by an attractive job market.

An important problem is to attract a sufficient number of U.S. citizens into our graduate programs of science and engineering, at a time when unprecedented numbers of foreign students are enrolled in our research institutions. During the period 1974 to 1981, foreign students accounted for almost 50 percent of the net growth in science and engineering graduate student enrollment.

In 1981 foreign students accounted for more than 20 percent of all full-time students enrolled in graduate science and engineering programs. They accounted for 43 percent of total full-time graduate students in engineering, 36 percent in mathematical and computer science, and 27 percent in the physical sciences.

Foreign researchers are accounting for an increasing proportion of postdoctoral researchers as well. In 1981 the proportion of postdoctoral trainees at doctoral granting institutions of foreign origin was 46 percent in physics and 68 percent in engineering. Some of these students remain in the U.S., but most return home, leaving us with a continuing lack of highly qualified and trained U.S. citizens to be faculty and researchers in crucial fields of science and engineering.

This, it must be emphasized, is not a problem of too many foreign students attending our institutions. Our world-wide role is a genuine strength and national treasure. This is, instead, the problem of our inability to attract a sufficient number of highly qualified and motivated American citizens.

The importance to our universities and our research enterprise of addressing this problem is underscored by the fact that in 1981, almost 30 percent of all scientists and 5 percent of all engineers in the U.S. were employed by educational institutions, primarily by our universities and our colleges. More than one-half of our doctoral level scientists and engineers are employed in our universities and colleges.

In the fall of 1981 an estimated 9 percent of all full-time engineering faculty positions were vacant. This shortage occurred despite a 12 percent increase in academic R&D expenditures (in current dollars) in engineering. Moreover, total undergraduate enrollments reached new heights, growing at 9 percent per year. This places great burdens on teaching faculty, who are increasingly hampered by outmoded research instruments and instructional equipment, and by outmoded research and instructional laboratories and facilities.